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A.N. Gushchin, S.I. Sanok, Y.S. Tatrnikova
Ural State of Architecture and Art, Russian Federation, Ekaterinburg, Svobodny 79
e-mail: alexanderNG@yandex.ru

INVESTIGATION OF THE SPATIAL DENSITY OF PUBLIC AND BUSINESS OBJECTS IN ALARGECITY WITH THE HELP OF GEOINFORMATION TECHNOLOGIES

Abstract: *The article is aimed at studying spatial distribution ofpublic and business objects' density with the use of geoinformation technologies. The data has been taken from the OpenStreetMapgeoinformation project. Earlier, we showed it to be a radial component of public and business facilities' density. This work is a continuation of the previous one. The angular distribution ofpublic and business objects' density is studied. It is demonstrated that the distribution is essentially asymmetric. Primary directions of the city development are revealed. The obtained results are interpreted by means of the "frame- fabric"model.*
Keywords: *GIS, geoinformation technologies, spatial distribution, "frame-fabric" model, angular distribution of density.*

Introduction

The Soviet urban planning school confined a functional approach to the management of area development, when each area had its own function: housing, industrial, recreational, etc. The core efforts in this approach seek to create the best planning structure through the optimal mutual placement of zones with a certain functional purpose. A prominent Soviet urban planner,

A. E. Gutnov was the first person who realized the shortcomings of this approach. The principle he expressed in the book "The Evolution of Urban Development" was the need to shift from the functional purpose of land to the description in terms of its use intensity. Thus, the term "urban planning system" was introduced that shifted "the center of gravity from urban research to the study of internal intrinsic interrelations of the facility and to the identification of the most common properties of its structural and functional organization (SFO)" (F.T.Gutnov, 1968, p. 57).

The mathematical formula describing cities in terms of their land use intensity is as follows: "revealing the dependencies between the basic properties of urban area F, D, T, where F is the type of functional use, D is the intensity of use, T is the location (positional properties)" (ibid., p.119). In other words, we are talking about the establishment of the following dependencies:

$$f = f(F,D,T) \quad (1)$$

In the international tradition, a similar approach originates in the work of the English economist and the statistician Colin Clark (1951), who studied the curves of population densities in 36 cities from Los Angeles to Budapest in the period since 1801 to 1950. As a result of the research, Clark obtained an exponential model of population density decrease depending on the distance from the city center

$$D = a * exp(-b*r) \quad (2)$$

where D is population density, r is the distance from the city center, a is the density in the central districts of the city, b is an empirical coefficient.

In the previous work, we investigated the law of diminishing the density of public- business objects, depending on the distance to the city center. This work supplements the previous one –

A.N.Gushchin, S.I.Sanok&Y.S.Tatrnikova (2107), and it is devoted to the study of the angular distribution of the spatial density of public-business objects. In combination with the previous radial distributions, this is an equivalent to studying the morphological structure of a city in polar coordinates. This method should be useful tostudy the structure of a compact city.

Methodology

The key research methods, as it is indicated in the title, are geoinformation technologies. In the research, the authors use the freely distributed QGIS (Quantum geographic information system) (Welcome to the QGIS project!, 2017). QGIS is a full-featured geographic information system closely integrated with online geo data.

As a data source, the authors use of the OpenStreetMap project (OpenStreetMap, 2017).This project ("open street map") is a non-commercial web-mapping project for creating a detailed free geographic map of the World. The community of theparticipants – Internet users maintain the set of maps. The project data is distributed under the terms of theOpen Database License (OpenStreetMap blog, 2017). The quality of the OpenStreetMap project data was investigated by Mordechai Haklay (2010). His findings showed that the information was accurate enough. A later investigation of the data accuracy was carried out by Barron et al. (2017) whoconfirmedMordechai Haklay's conclusion. The geo data samples used for the Russian regions can be found in the paperby Yu.Kruglov, V. Stetsurina and E.S. Snezhkina(2013). Thus, we can use the geo data from OpenStreetMap as completely reliable. The obtained activity map is demonstrate in Fig.1.

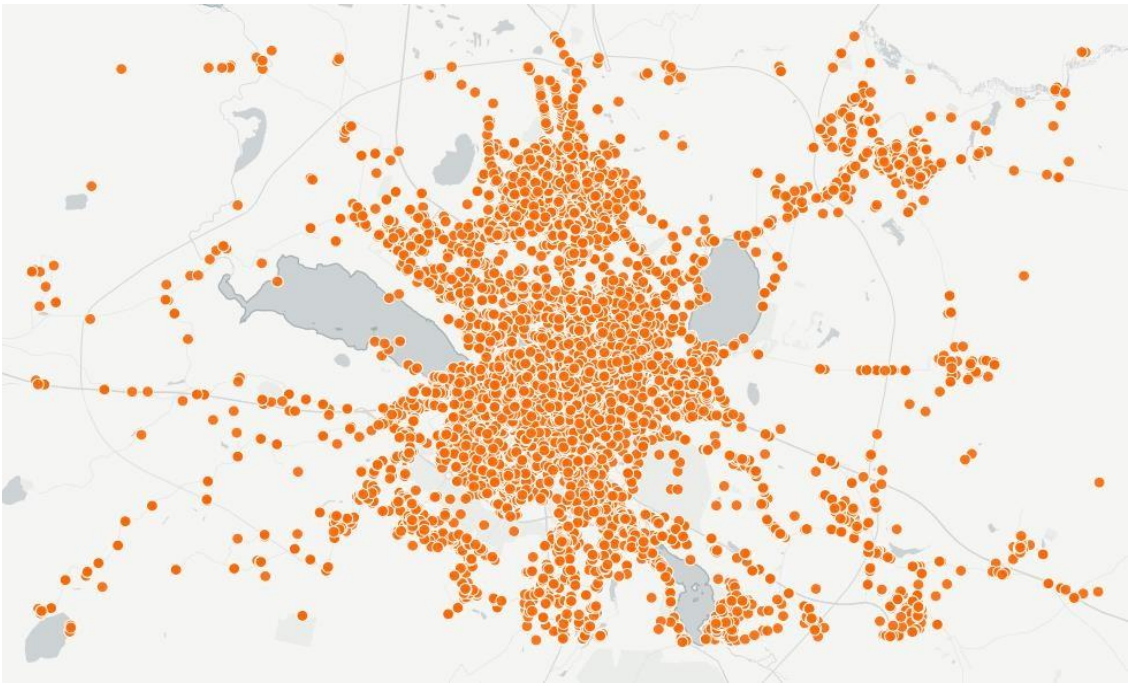

Figure 1. Spatial distribution of public and business objects in Ekaterinburg. Source: the authors

In total, the following types of 11,886-point features have been imported: banks and insurance companies, consumer services, vet medicine, hotel services, businessmanagement, healthcare, cultural institutions, shops, scientific activities, public education, catering, public administration, entertainment, religious establishments, markets. The classification of the objects is made according to the official document (the Ministry of Economic Development ofthe Russian Federation, 2014).

To construct the histogram, the authors have made two calculations: for the first calculation, the area has been divided into fifteen rings each by 1.45 km wider than the previous one. Then,

using the QGIS system, spatial queries have been performed to select objects inside a specific ring, after which the number of activities has been recalculated into the spatial density – the number of objects per a square kilometer. When calculating the objects spatial density, the authors have made amendments related to unused land: industrial zones, water bodies, etc. that could lead to distortion of theresults.

Figure 2 illustrates the scheme of calculating the angles for each object. The formula for calculating the angle between the fixed axis "north-south" with the origin in the common system of coordinates of the circle centers, and the direction given by the sector drawn from the origin to the point where the next object is located is shown below.

$$\varphi_i = \pi/2 - arctg\ ((y_i - y_0) / (x_i - x_0)) \quad (3)$$

Here (xi, yi) are the coordinates ofiobject falling into the ring. (x_0, y_0) are the coordinates of the center common to all the circles. Further, a histogram has been constructed from the obtained angles with an interval of 20°. These histograms are constructed for each ring. An example of a histogram of the angular distribution for the first spatial ring is demonstrate in Fig.3.

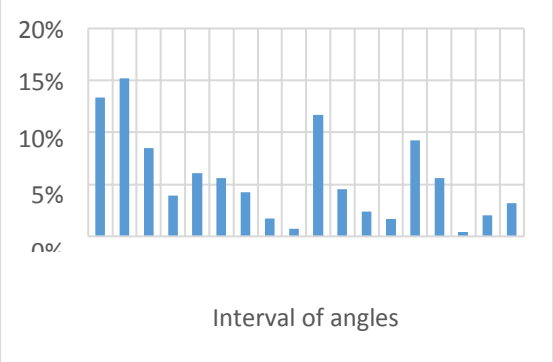

Figure 1. The scheme of calculating the angles for each social and business object. Source: the authors

Figure 2. Histogram of the angular distribution of objects for the first ring. Source: the authors

The homogeneity of the public and business objects' distribution is also checked by the characteristics of the angular distribution of public and business objects. It can be expected that for cities with a compact structure the angular distribution will be isotropic (homogeneous). The characteristics of the histogram in Fig. 3 cause us to doubt the hypothesis of homogeneity. To check the homogeneity of the distribution, a well-known statistical criterion has been used (A. Ayvazyan, V.S. Mkhitaryan,2001).

Results and discussion

The general morphological characteristics of the spatial distribution shown in Figure 1 are as follows: the nearest neighbors index is 0.34. The index of the nearest neighbors - a characteristics adopted fromgeostatistics - represents the average number of the nearest neighbors for each object (G. Materon, 1968). The calculated value indicates a strongly clustered character of the spatial distribution, i.e. indicates that the spatial distribution of objects is not homogeneous, and objects tend to cluster - clustering.

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$$X = S_n / X_{cp} \quad (4)$$

where χ is the coefficient of variation, S_n is the standard deviation for a sample of n points, and $X_{cp}$is the mean. The value of the criterion χ <33% indicates that the sample is homogeneous, i.e. that the differences in the data values are due to random causes. In our case, the value of the criterion χ> 33% allows us to reject the hypothesis of homogeneity.

The analysis of the data on the angular distribution within other spatial rings makes it possible to determine the preferential directions of urban development. For this purpose, two values have been calculated: the average number of public-business objects within a spatial ring with the number N, and the number of objects lying in the sector of 100-120 degrees (sector "south-east") – Figure 4.

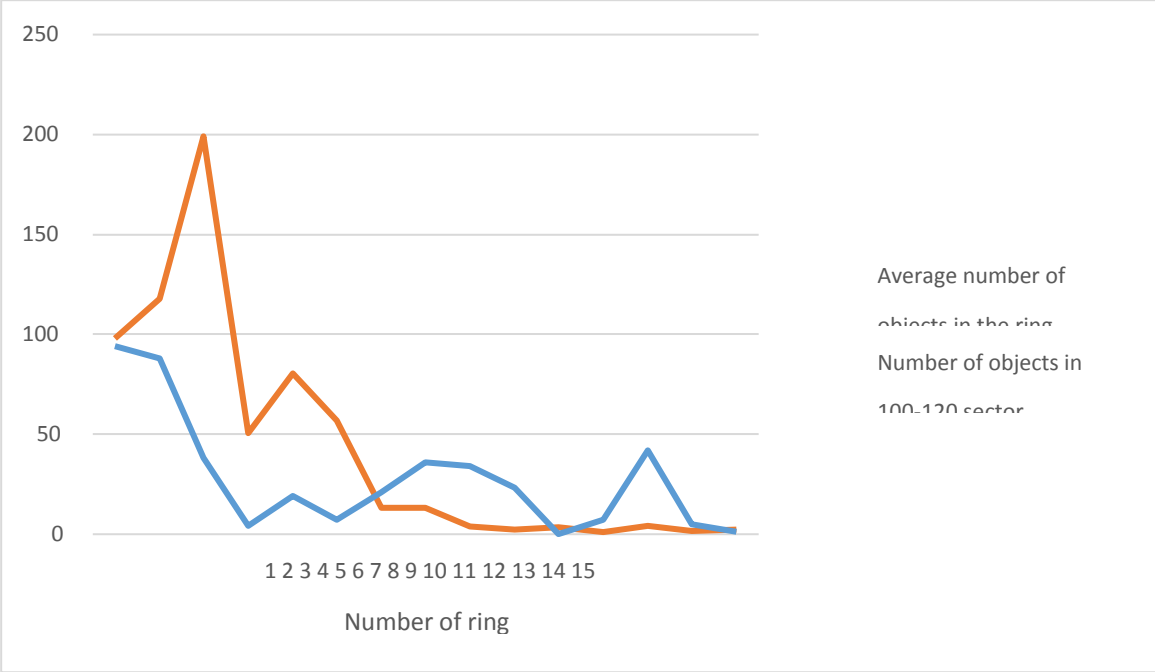

Fig. 4. The number of public-business objects inside on average
and within the selected direction "south- east". Source: the authors

The difference between the two types of the curves' behavior is clearly visible in Figure 4, namely, the rate of thedecrease in the number of objects in the southwest beam is significantly smaller than the average rate of the decrease in the number of objects. The authors believe that this behavior is related to the availability of high-quality transport highways and the construction of large public and business facilities: an exhibition site for exhibitions "Innoprom", located near the route to the Koltsovo airport that led to a further increase in the number of public and business facilities. From the theoretical point of view, Fig. 4 is an excellent illustration to the "framework and fabric" model. The long "tail" of the sample along the ray "south-east" is a forming a frame. According to A.E.Gutnov, the frame is formed, in particular, at the expense of large public and business objects: "in one case the high intensity of development may be due to a combination ofbusiness facilities concentration with the related services, in another case due to a powerful cultural and recreational center, in the third one due to the trade and service center of a housing estate, etc. " (A.T.Gutnov, 1968, p. 43). That confirms the authors' point of view. The second feature of the graphs in Figure 4 is the sharp peak of the number of objects in the region of the third spatial ring. This effects is largely due to the effects of calculation. If you recalculate data not by the absolute number of objects, but by their spatial density (the number of objects per square kilometer), then the effect is notobserved.

At thefirst glance, experienced come to the same conclusions specialist simply looking at Figure 1. An expert can identify the direction "north-west" as a probable direction fordevelopment.

An expert can identify not only the "south-east" direction considered above as a probable direction for development, but also the"north-west" direction and possibly other directions. However, here the advantage of quantitative calculations is revealed.

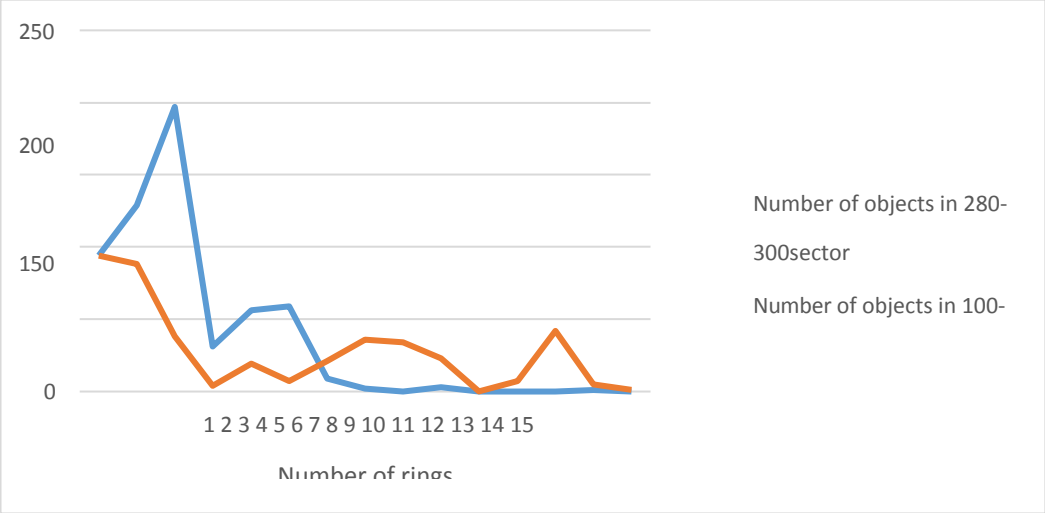

Figure 5. Comparing the number of objects in the “south-east" and "north-west" directions
Source: teh authors

Comparison of the number of objects in the "north-west" and "south-east" directions shown in Figure 4, shows that in the “north-west” direction there is no this extended "tail" of public-business objects as in the “south – east” direction. This means that the "south- east" direction is today the most likely direction of the urban development. The figure shows a sharp increase in the number of public and business facilities in the area of the third spatial ring. A similar picture is observed in Figure 4. Given the local nature of the observed maxima - they are all limited to a certain sector; we can conclude that there is a change in the model of the urban growth. If earlier the city developed as a city with a compact radial layout, now it can begin to develop according to a multi-core Harrison-Ulman model. Visually, this development will be expressed in the appearance of compact areas of high-rise buildings, saturated with public and business facilities. The city administration at public hearings claimed that the city will no longer grow wide, but will develop due to high-rise buildings. This confirms the above assumptions.

To obtain acomposite characteristic of the angular distribution of objects, the authors have used the following method. For each angular sector, the total number of objects located within each spatial ring has been calculated. In the obtained variation series, the median has been calculated. Then its position has been determined graphically and the obtained values have been connected together, forming a polygon. The results are demonstrated in Figure 6. The figure demonstrates the central core of the city. It represents a geometric figure without noticeable asymmetry. At the same time, it can be said that a planning axis is being formed in the"northwest" - "south-east" direction. The data in Figure 6 agrees with the data obtainedearlier.

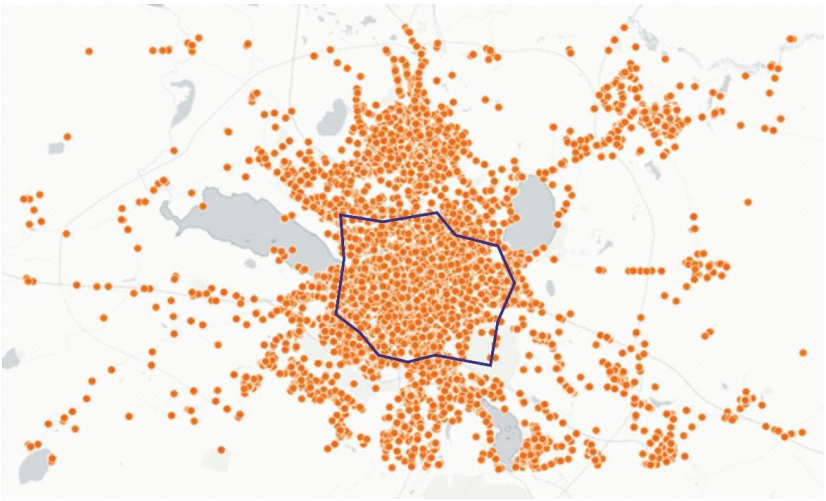

Figure 6. Composite characteristic of the angular distribution. Source: the authors

Conclusion

In general, the analysis done in the work is consistent with the idea of the city spatial structure that is described in the master plan as a "compactly dispersed, radial planar structure" [15]. At the same time, the analysis using geoinformation technologies and methods of exact sciences makes it possible to reveal the characteristics of the city spatial development in the direction of the primary development, the type of urban development more accurately. The practical benefit of this research is the general methodological significance of the methods proposed as a universal means of studying the most common territorial-spatial aspects of urban morphology.

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